CONF-860487--3

LA-UR -85-4066

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LA-UR--85-4066

DE86 003659

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SUBMITTED TO Robots 1986, April 20-24, 1986, Chicago, IL

APPLICATION OF TELEOPERATOR EXPERTISE TO ROBOTICS

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INTRODUCTION

The Clinton P. Anderson Meson Physics Facility (LAMPF) has operated at beam currents above 200 microamperes since 1976. Since then the radiation levels have steadily increased from 100 mR/hr to levels that exceed 10,000 R/hr in the components near the pion production targets. During this time, the LAMPF remote handling system, Monitor, has continued to operate in the ever-increasing radiation levels, as well as in more complex remote-handling situations. The philosophy of the Monitor system is to use only viewing by television, electric master-slave servomanipulators, and distance instead of shielding for radiation exposure control. An overall view of LAMPF is shown in Figure 1.

This paper will briefly describe the evolution of Monitor and its present capabilities and accomplishments. It will also suggest that the equipment and operational expertise can be applied to robotic systems in radioactive and other hostile environments. The Monitor methods of operation, tooling devised and employed, and the applications of these methods to robotic systems will be described.

Figure 1. Overall view of LAMPF.

HISTORY AND DESCRIPTION OF MONITOR

The Monitor system was developed during 1975 and 1976 and was placed in operation in the fall of 1976. It then consisted of a hydraulic servomanipulator and a small electromechanical manipulator mounted on a one-ton hydraulic crane as shown in Figure 2. It was controlled from two electronic racks and a simple master arm located in the experimental hall as shown in Figure 3. Although we were able to do useful work with this crude system, further evolution was necessary to deal with the more complex operations of which it is capable in its present advanced state.

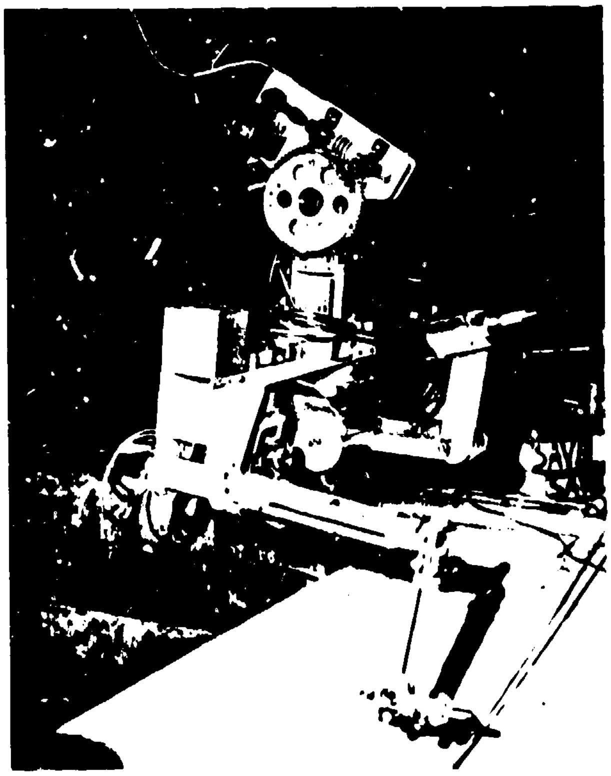

Figure 2. Original Monitor system slave unit.

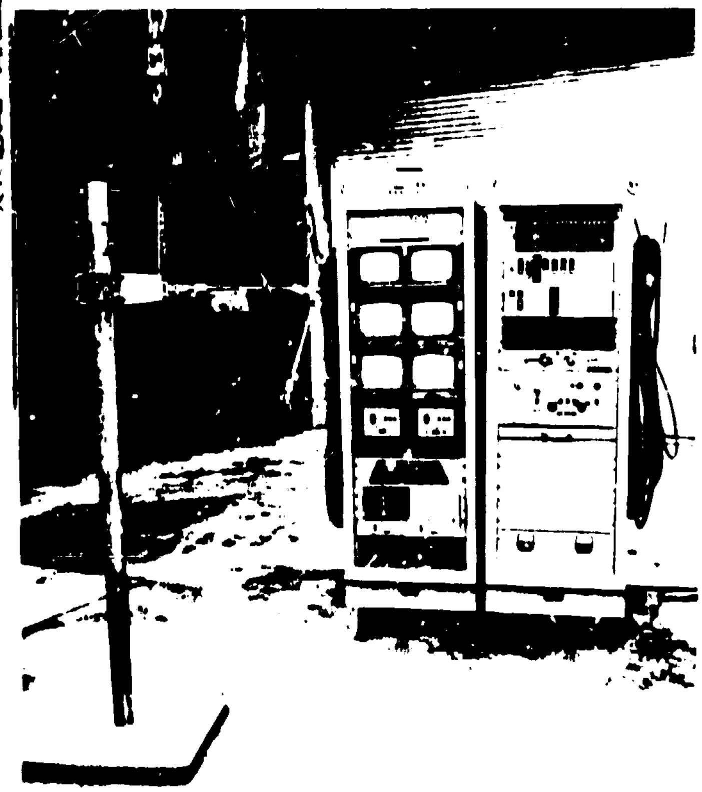

Figure 3. Original Monitor control station.

The first major improvement was the acquisition of a pair of electric master-slave servomanipulators with force feedback, which increased both the speed and dexterity of the system. Other additions include better hydraulically operated "pan/tilt" units for the manipulators, state-of-the-art pan/tilt units for the video cameras, and vastly improved lighting. Figure 4 shows the present configuration of a typical slave unit.

The next step was to add a more complete control room, installed in a trailer, which provides an isolated, relatively comfortable place to do the tedious, demanding job of remote handling. It consists of the servomanipulator master arms, a large video display for the manipulator operator, and control stations for both the large crane and the numerous video cameras as shown in Figure 5. Normal operations are performed with three operators, which allows cross-training and relief from the tedious job of manipulator operator.

We then added a second identical unit to allow simultaneous work at two of the four target stations. The final step provides a third system with all the capabilities of the other two, but which is self-contained with its' own engine-driven generator and able to do remote handling at any location where a truck can go.

Figure 4. Present Monitor system slave unit.

Figure 5. Present control station.

As shown, each of the Monitor units is composed of (1) A slave unit that places the manipulators at the work location, provides video coverage of the area of interest, and gives audio feedback from the operations being performed, and (2) A master station that provides control of the manipulators, as well as the video systems, tool operations, and other functions required to successfully complete the required remote tasks. Interconnecting wiring between the master and slave stations includes the manipulator closed-loop servo signals, video signals, numerous on-off signals for tools, camera pan, tilt, zoom, and iris controls, and the hydraulic crane controls. This cabling is normally 100 meters long, but can be extended to several hundred meters. Each control function has been individually hard-wired between the master and slave stations, but the operational testing of a multiplexing system for camera controls is now in progress.

Additional improvements now in the planning stage include digital control of the servomanipulators and use of a fiber optics link from the master to slave stations.

TOOLING

The tooling philosophy for the Monitor system is:

- Use standard tools if at all possible and only modify them to adapt to manipulator use.
- If standard tools are not available, design and build whatever is necessary.

Figure 6 shows examples of the first category, a commercial impact wrench and an air power tube nut wrench, both slightly modified for manipulator use.

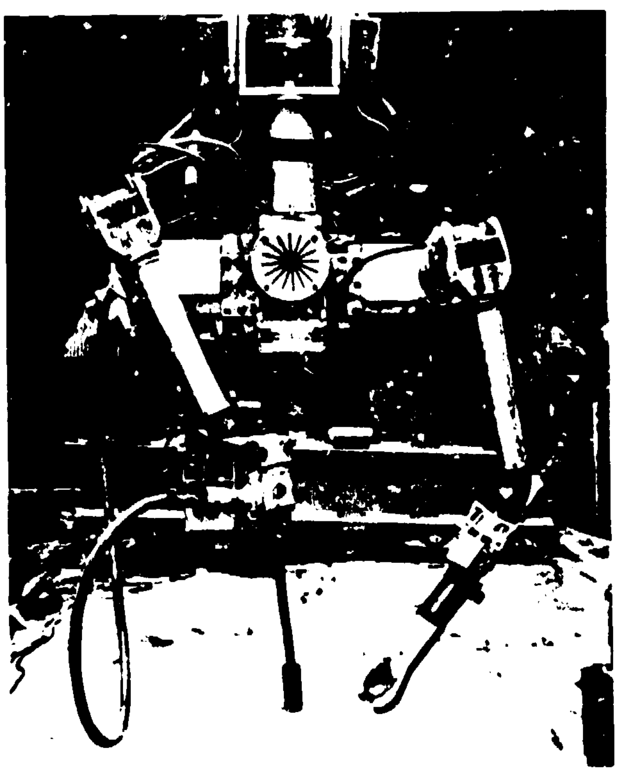

Figure 6. Commercial tooling.

Figures 7 and 8 illustrate tools designed in-house, the first a special oxy-acetylene soldering/brazing torch with a remotely controlled filler material feeder, the second a tube nut rachet wrench modified to reach a particularly inaccessible nut.

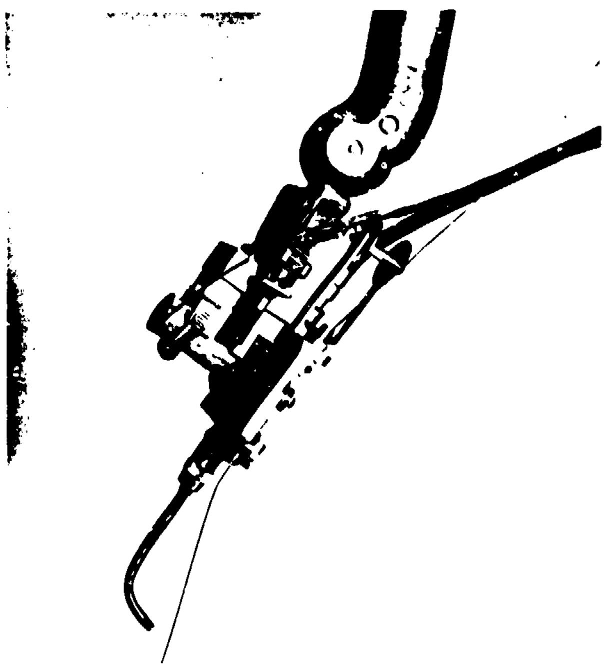

Figure 7. Soldering/brazing tooling.

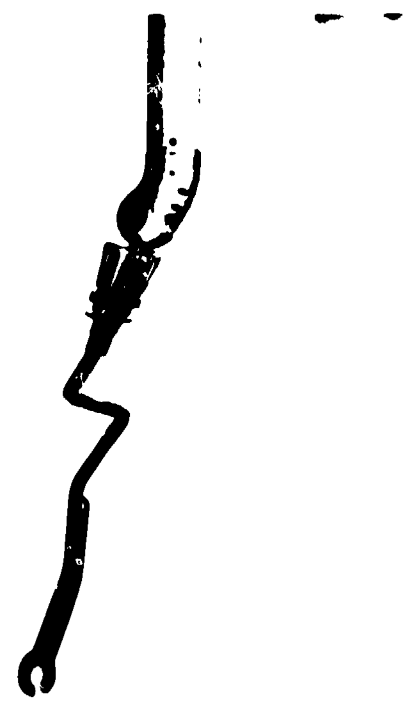

Figure 8. Specially modified tube-nut wrench.

EQUIPMENT

The present Monitor systems contain most of the mechanical hardware necessary for implementing a hybrid system capable of functioning both in teleoperator and robotic modes. The present analog control system could be retained for teleoperator mode of operation; however, the overall modification would be cleaner if both operating modes employed digital control systems.

MODES OF OPERATION VERSUS TASKS

Figures 9 and 10 provide views of typical work areas at LAMPF.

The following is a list of a few typical tasks performed in nuclear installations and preferred modes of operation.

TASK	MODE OF OPERATION
Troubleshooting	Teleoperator
Emergency repairs (leaks, electrical shorts, etc.)	Teleoperator
Assembly/disassembly of bolted components	Robot
Materials transfer	Robot
Welding and flame cutting	Robot with teleoperator supervision

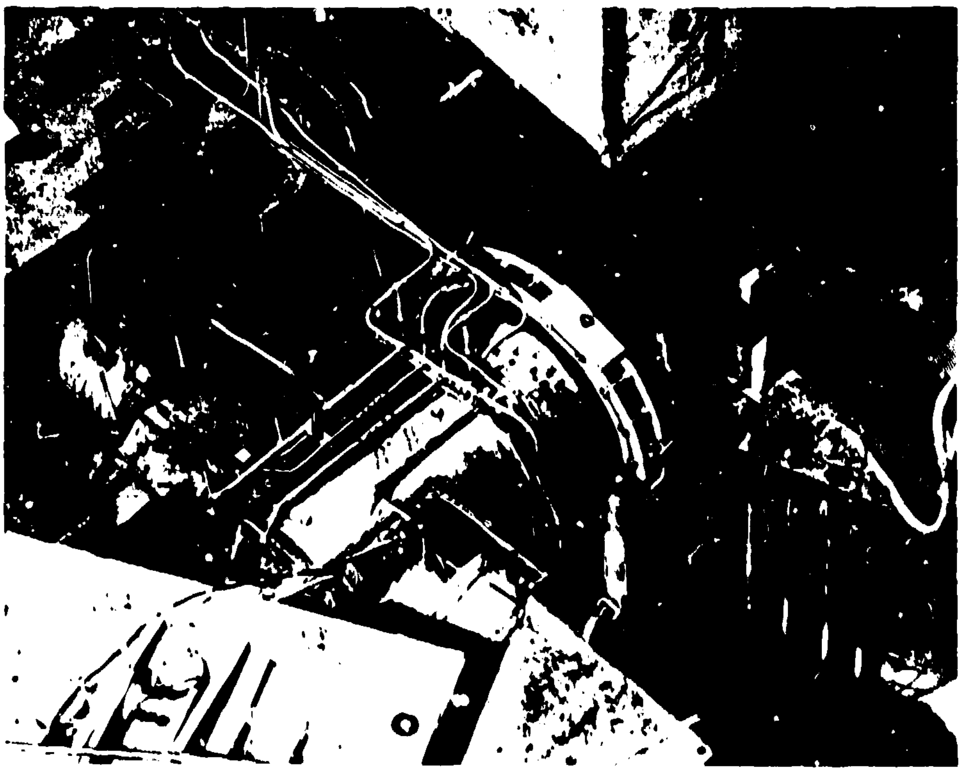

Figure 9. LAMPF target cell.

Figure 10. LAMPF target cell under reconstruction.

PROGRAMMING

Programming for the robotic mode could be performed by:

1. Normal robotic teach mode using the teleoperator capability to lead the robot through the required steps. This could be both in a normal and hostile environment.

2. Downloading numerical control data from CAD/CAM system into the robotic programmable controller.

ADVANTAGES

1. Robots can be taught skills requiring a high degree of manual dexterity (such as welding) in a normal environment, then the work can be performed automatically in a hostile environment.

2. Human error can be eliminated in situations where collision avoidance is a problem in the teleoperator mode of operation.

3. Cost of implementation is considerably reduced by using existing hardware and tooling.

4. Operator stress and fatigue will be greatly reduced.

CONCLUSIONS

The teleoperator mode of operation cannot be eliminated in large facilities where radioactive equipment is present; however, operating efficiency can be greatly increased by performing routine and well-defined operations in the robotic mode.